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I. ABSTRACT

Optical Properties in coastal waters change rapidly on very fine spatial scales. The existence of multiple ocean color systems provides a unique capability to monitor coastal waters and to define spatial variability by providing multiple “looks” per day at different spatial resolutions. However, to take advantage of data from multiple sensors, the processing methods and derived optical products must be consistent and require sensor inter-calibration. We examined the statistics of the 1km sub-pixel variability using higher resolution imagery. We evaluated the consistency of the inherent optical properties (absorption and backscattering) derived from multiple ocean color sensors at different spatial resolutions.

We examined optical variability over small spatial scales in different areas and assessed differences in the satellite-derived optical products. Coastal optical properties derived from the 1 kilometer resolution Moderate Resolution Imaging Spectroradiometer (MODIS) sensor were compared with 100 meter resolution Hyperspectral Imager for Coastal Ocean (HICO) and 300 meter MEdium Resolution Imaging Spectrometer (MERIS). We show examples of multi-sensor, blended products to demonstrate the benefit of multiple scenes per day to reduce the impact of cloud-covered pixels.

Our results show 1) combined ocean color sensors can be used to better characterize the optical properties in coastal areas, 2) small spatial scales can be re-sampled to larger spatial scales for inter-satellite and product comparisons, and 3) larger scale ocean color imagery does not adequately represent spatially complex coastal waters.

II. OBJECTIVES

- 1 Show optical variability over small and large spatial scales using HICO, MERIS and MODIS Aqua imagery.
- 2 Examine the mean and variance relationships associated with re-sampling small scale HICO imagery (100 meters) to larger scales (300 meters, 500 meters, 700 meters, and 1 kilometer).
- 3 Examine consistency between optical properties from multiple ocean color sensors with different spatial resolutions.
- 4 Demonstrate the advantage of blending daily optical properties from multiple sensors to reduce the impact of cloud-contaminated pixels, glint, and atmospheric and algorithm failures.

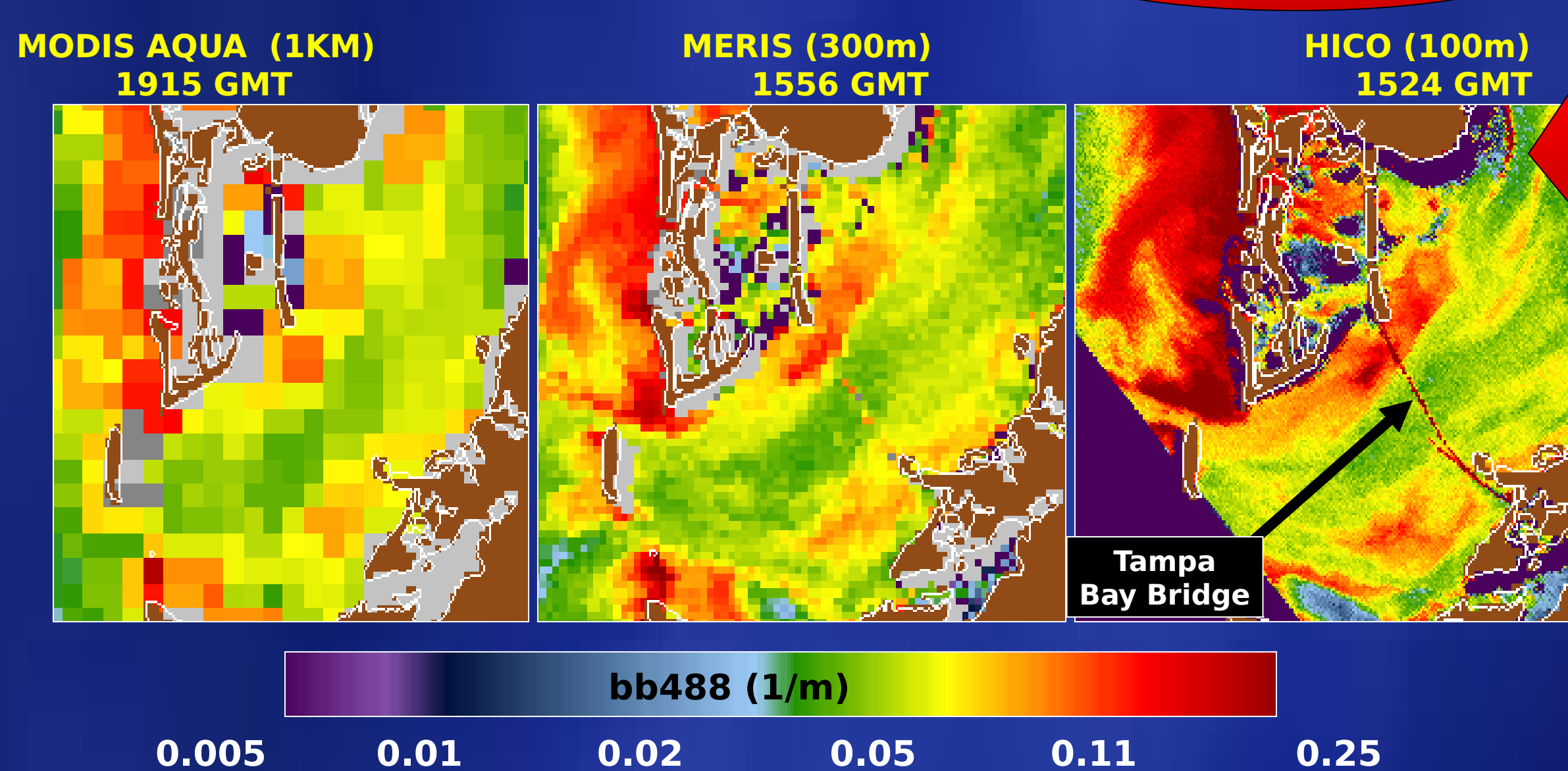
III. SATELLITE IMAGE PROCESSING

(HICO 100m, MERIS 300m, MODIS Aqua 1km)

HICO is a high resolution (100m) hyperspectral (128 bands) sensor developed by NRL that is currently deployed on the International Space Station. To aid in the comparison between HICO and the coarser resolution sensors, the HICO hyperspectral bands were convolved to simulate the 9 MODIS bands. MERIS images at 300 meter and 1 kilometer spatial resolution and MODIS images at 1 kilometer spatial resolution were used in this study. Coincident images (within @ 7 hours) from Bahrain, Djibouti Coast (Africa) and Tampa Bay were selected for comparison. For all three study sites and for each of the three sensor data sets Absorption [a], Backscattering [bb], and Beam Attenuation [c] Coefficients were derived using version 3.9.2 of NRL's Automated Processing System. The Gordon/Wang atmospheric correction with a NIR iteration and absorbing aerosol correction (Stumpf) was applied. Inherent Optical Properties were derived using the Quasi-Analytical Algorithm (QAA).

IV. OPTICAL AND SPATIAL VARIABILITY

Tampa Bay, Florida 10/20/09

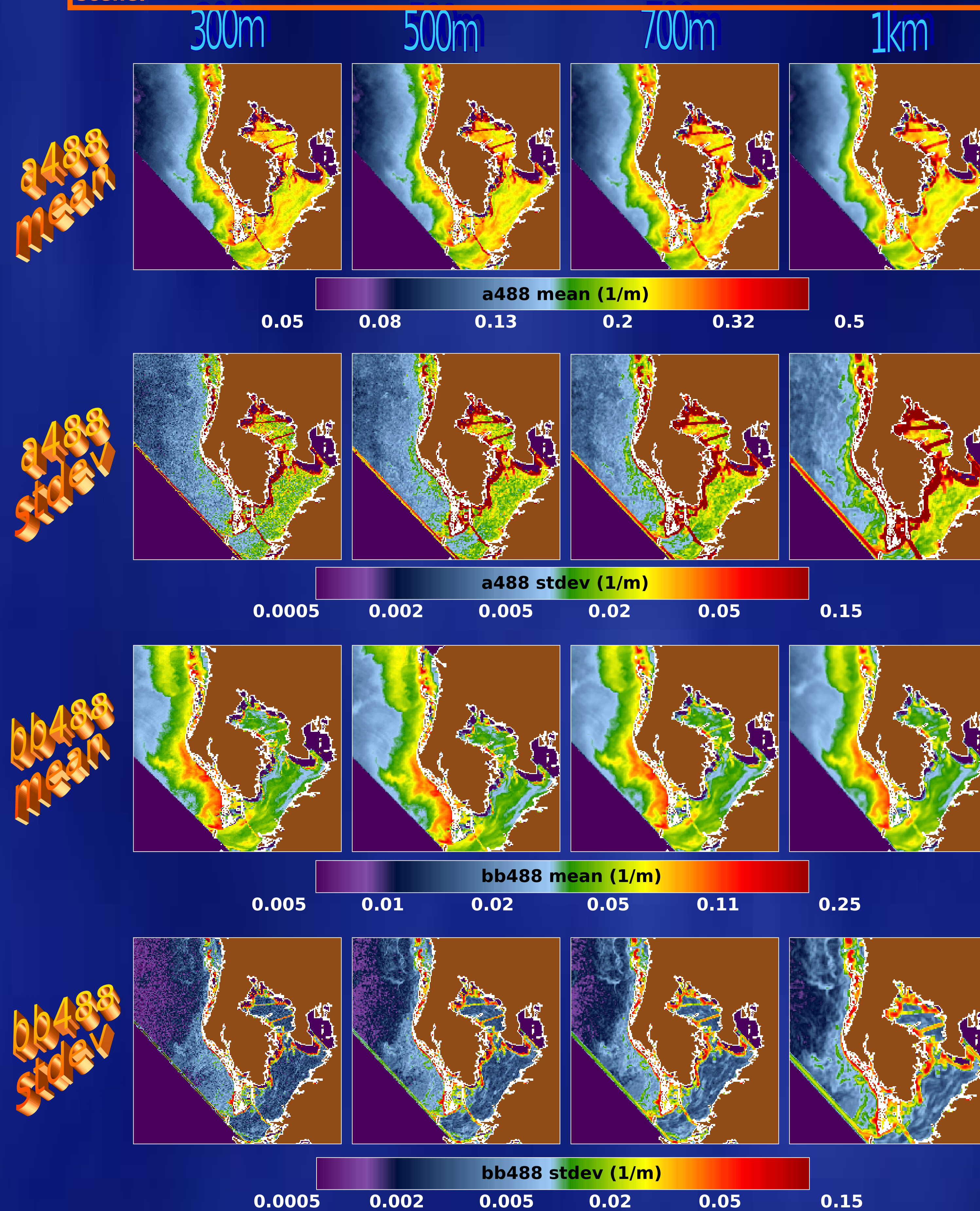


NOTE: Small scale images are better in resolving complex coastal optical features and monitoring coastal processes. Derived backscattering for all three sensors are consistent. HICO calibration issues are being addressed and vicarious calibration applied for consistency with other sensors. (See Poster IT35A-07 by David Lewis)

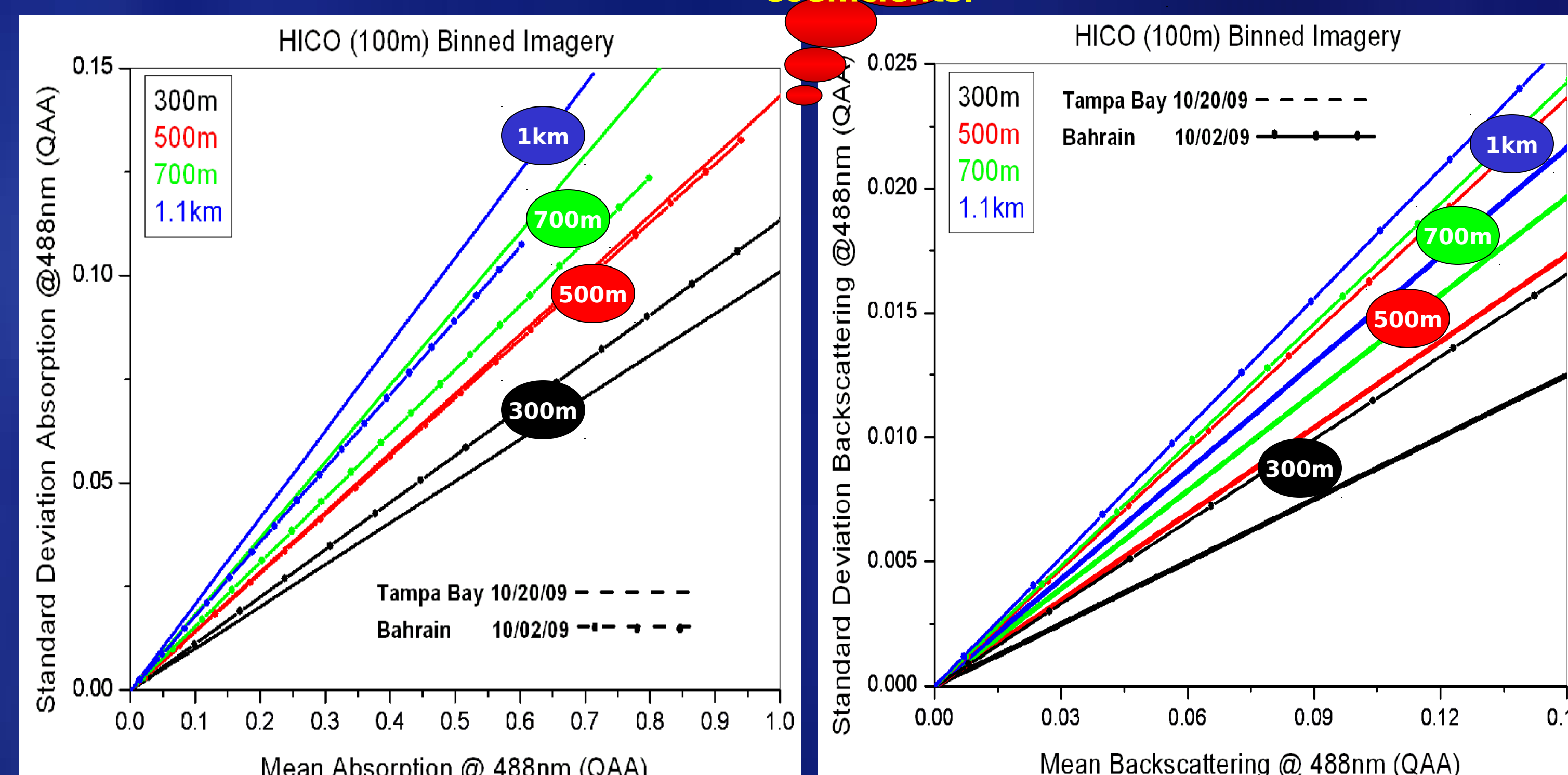
V. OPTICAL VARIABILITY OVER VARIOUS SPATIAL SCALES WITH MEAN AND STANDARD DEVIATION RELATIONSHIPS

HICO 100m Tampa, FL Oct. 20, 2009 1524 GMT

Statistics (mean and stdev) and images were generated using sliding windows of 3x3 (300m), 5x5 (500m), 7x7(700m) and 10x10 (1km) pixels from the 100m HICO scene.



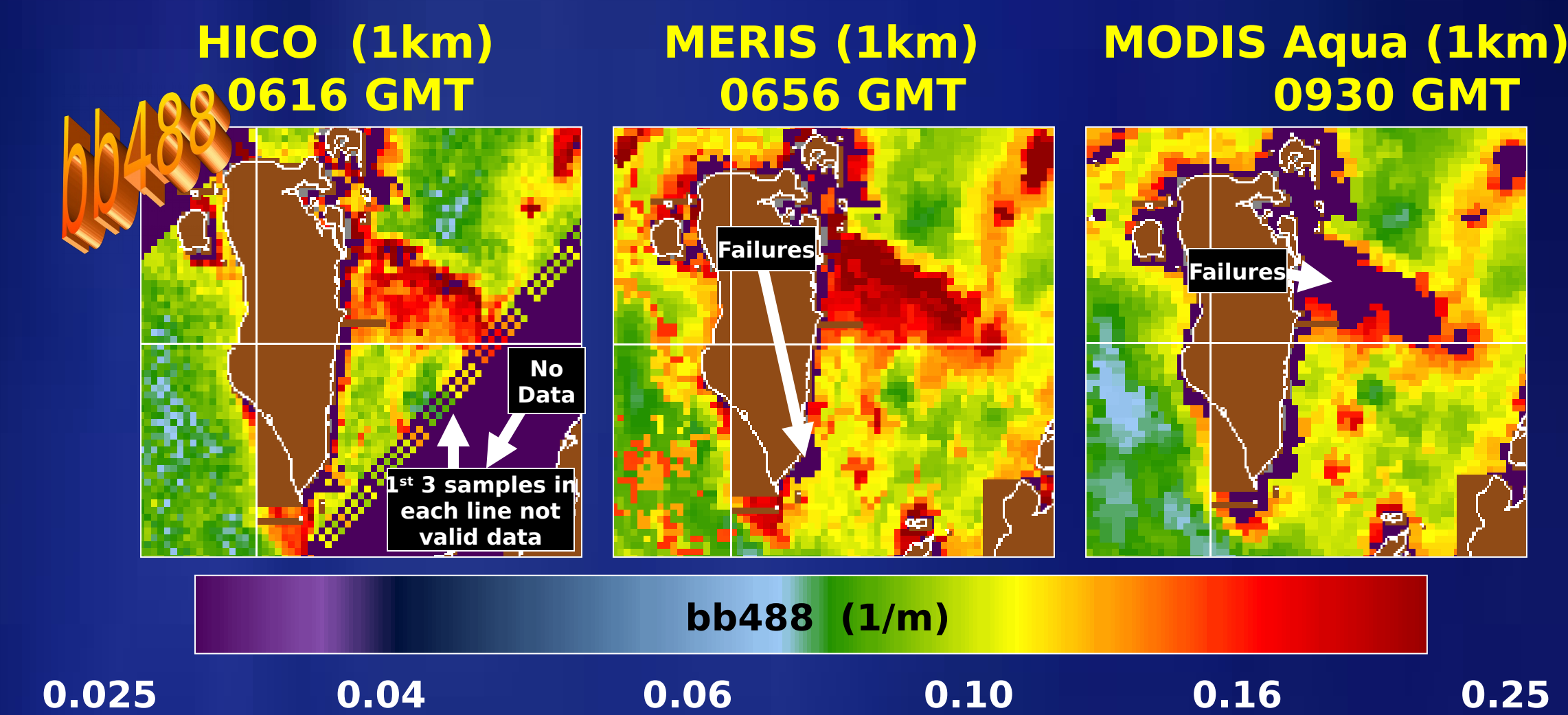
Increase in Box Size Yields Increase In Standard Deviation For Absorption and Backscattering Coefficients.



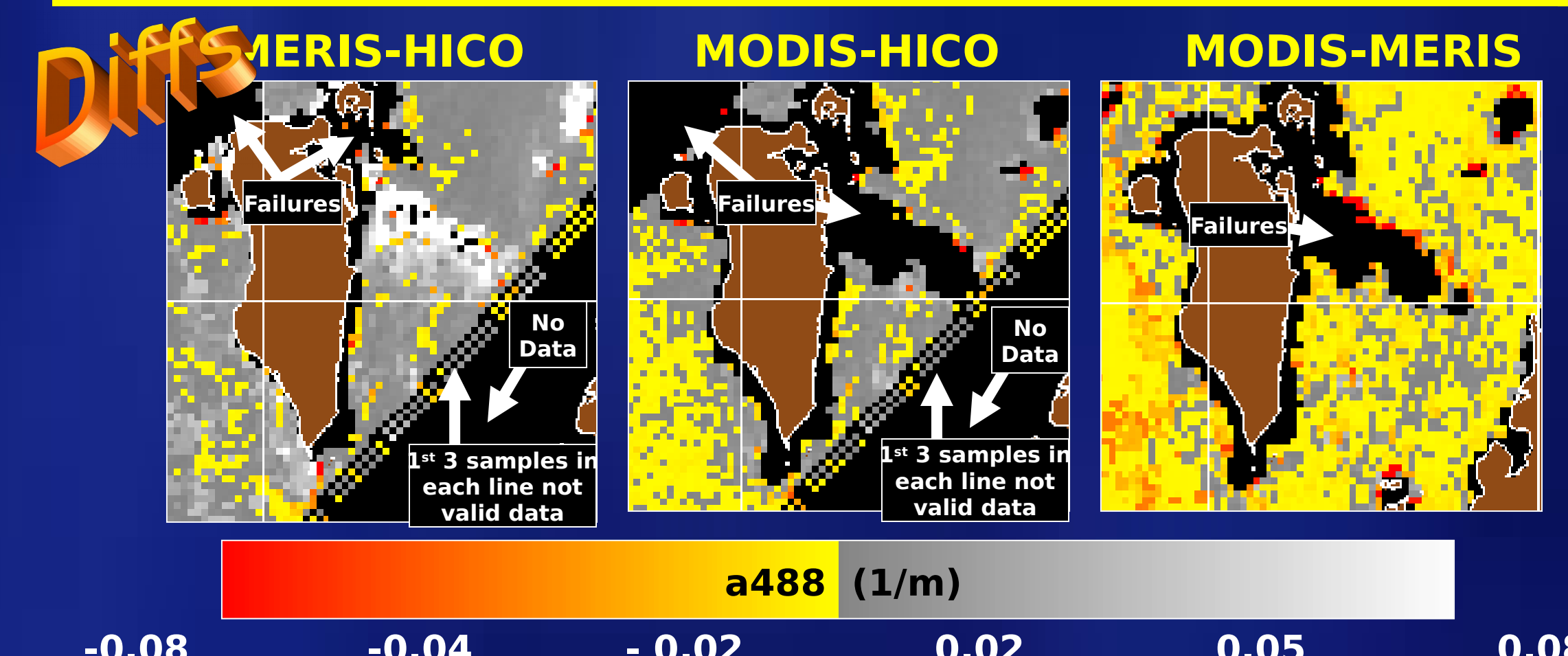
NOTE: HICO data sets were resampled to the 300 meter and 1000 meter spatial resolution to facilitate comparison with MERIS and MODIS. In addition, to analyze intermediate re-sampling intervals, HICO data sets were resampled to 500 and 700 meter. Statistics (mean and standard deviation) were generated from moving windows (bins) of 3x3, 5x5, 7x7, and 10x10 pixels over the HICO data. These statistics represent the variability in the finer resolution data over the cell sizes of the coarser resolution data sets. The mean absorption and backscattering estimates are similar with increasing bin size (coarser image resolution). The standard deviation of absorption and backscattering behaved similarly for the Tampa Bay, FL and Bahrain HICO images, increased with an increase in bin size (coarser resolution).

VI. MULTI-SENSOR OPTICAL CONSISTENCY

Bahrain Oct. 02, 2009



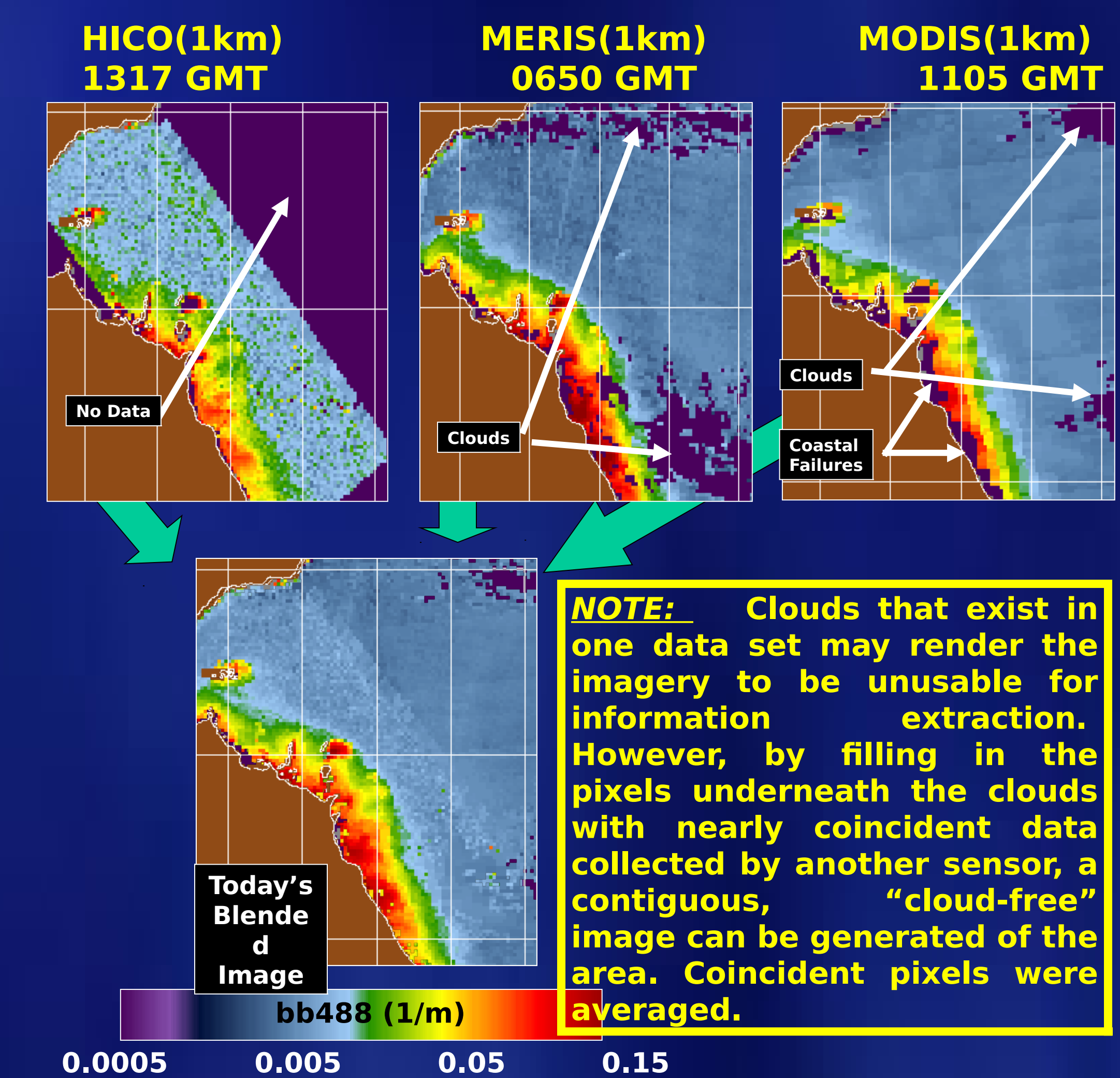
NOTE: Comparisons were made between HICO, MERIS and MODIS optical properties all at 1km from Bahrain. A scaling factor was applied to the HICO optical properties for consistency. MERIS and MODIS compared well with HICO. Purple areas in images are due to no data, algorithm/atmospheric failures or edge of swath.



NOTE: MODIS and MERIS had the biggest differences. Difference might be due to collection times. MODIS was collected 3+ hours after HICO and MERIS. Orange to yellow pixels represent (-) differences, B/W pixels represent (+) differences.

VII. MULTI-SENSOR DAILY OPTICAL BLEND

Djibouti Coast Dec. 05, 2009



NOTE: Clouds that exist in one data set may render the imagery to be unusable for information extraction. However, by filling in the pixels underneath the clouds with nearly coincident data collected by another sensor, a contiguous, “cloud-free” image can be generated of the area. Coincident pixels were averaged.

VIII. SUMMARY

- Statistics of absorption and backscattering measurements from the Tampa Bay, Florida image were drawn from moving windows (bins) with different spatial resolutions (300m - 1km). The standard deviation increases as the size of the bin, from which the statistics are drawn, increases. The ratio of the stdev to mean (coefficient of variation) provides a measure of homogeneity within the sampling bin. This ratio also increases with increase in bin size.
- Combined ocean color sensors can be used to better characterize coastal optical properties.
- Small spatial scales can be re-sampled to larger spatial scales for inter-satellite and product comparisons and blending.
- Larger scale ocean color imagery does not adequately represent spatially complex waters.